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PATH TO 2007

EMA Comments to the CDIRP on EPA's June 2002 Highway Diesel Progress Review

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EMA has made presentations to the Clean Diesel Independent Review Panel (CDIRP) at its June 27, 2002 and July 30, 2002 meetings. Copies of those presentations are attached. Members of the Panel also expressed an interest in having EMA provide additional comments on EPA's June 2002 "Highway Diesel Progress Review" (the "EPA Report") and additional information on the progress of engine manufacturers towards compliance with EPA's 2007 Heavy-Duty On-Highway engine emission standards.

As EMA stated in its prior presentations, and as we re-emphasize here, we believe that in addition to the CDIRP review it is critical for EPA to re-assess progress towards 2007 in the mid-2003 time frame. We note that EPA has agreed to such a review. A great deal of progress towards compliance already has been made and more will be made in the next year, and beyond. However, while the effect date for compliance with the 2007 emission standards is the 2007 model year, engine manufacturers do not have until that model year to continue to develop technology. At some point substantially in advance of the effect date, and by no later than mid-year 2003, manufacturers must establish the practicality of the technologies to be implemented so as to provide themselves the leadtime necessary to complete the complex optimization and vehicle integration processes that are required to successfully implement aftertreatment technologies. Engine, aftertreatment and vehicle manufacturers also require leadtime to order tooling, obtain capital, approve production parts, conduct durability and field testing.

EMA's comments on the EPA Report are based on the practical realty that technological feasibility needs to be evaluated on the potential for candidate compliance strategies to meet the fully phased-in standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM. These requirements must be met under all of the regulated test procedures, at the expanded ambient conditions and at up to 435,000-mile useful life. As EPA correctly states, plans for 2010 NOx compliance are designed to build upon the starting approaches used in 2007 (see EPA Report at page 23). We agree that manufacturers cannot afford to develop, manufacture and service multiple, major technologies over such a short time frame. Therefore, the technology pathway for achieving the fully phased-in emission standards must be thoroughly understood well in advance of 2007. Further, the feasibility of each technology must be evaluated within a framework of its functionality, durability, and cost for the complete range of conditions faced in engine use. As noted above, EMA identified the need for engine manufacturers to make a final selection of a technology path in July 2003 in order to allow for adequate time for product development and production implementation. Manufacturers can only make this selection, and move ahead with the development programs, if the critical technologies have evolved sufficiently to allow manufacturers to be able to project with reasonable certainty that those technologies will be successful.

Technical feasibility should be determined against a defined set of criteria requirements. The criteria requirements are functionality (e.g. emissions; performance; reliability); durability (e.g. useful life); and cost (e.g. first cost; fuel economy; maintenance; installation impact; infrastructure). EMA's comments use those criteria in assessing the EPA Report.

I. PARTICULATE FILTERS

A. Filter Efficiency

There is general agreement that catalyzed diesel particulate filters (CDPF) are highly efficient and, when used in conjunction with ultra low sulfur diesel fuel ("ULSD" – fuel with <15 ppm sulfur), and when applied to current technology engines, are capable of reducing particulate emissions to 0.01 g/bhp-hr PM. Without ULSD, a 0.01 g/bhp-hr PM standard cannot be met due to "sulfate-make." The availability and use of ULSD is essential to the use of CDPF.

B. Regeneration

Passive CDPF's have been shown to operate effectively in certain real world applications. EPA notes the success of these systems in their report and relies on this experience to conclude that particulate filters "will be broadly applicable by 2007." However, today's experience with CDPF's is largely limited to select applications that provide a combination of ambient temperatures, low sulfur fuel and operating conditions that are conducive to passive filter regeneration.

In order to be broadly applied, as is necessary under the regulation, filter systems must be capable of regenerating during service in a range of duty cycles that vary widely in load factor and temperature characteristics. For example, filter systems will need to be as capable of regeneration on a lightly loaded pick-up truck idling in northern Minnesota as it is on a line-haul truck pulling a full load up a grade in the middle of summer. Since the engine manufacturer does not know how or where a specific engine will be operated, each engine must be equipped with a filter system capable of regeneration under "worst case" conditions. In order to do that, manufacturers will be required to implement active, not passive, regeneration systems.

Active regeneration systems are more costly and more complex than passive regeneration technology. They require more maintenance, are less reliable, and increase fuel usage. While passive regeneration systems are feasible and currently available, substantial development is still required before the availability of practical and reliable active regeneration systems can be assured. Success is likely, but is not a foregone conclusion.

C. Ash Removal/Filter Cleaning

One of the hurdles to the commercialization of CDPF's is the need to address several issues associated with filter cleaning. Filter cleaning is required to remove the ash that builds up in CDPF systems. Filter cleaning typically will require removal of the particulate filter from the vehicle and, consequently, results in non-productive vehicle downtime.

Filter cleaning will require the development of an infrastructure and the development of environmentally sound practices for ash removal, handling, and disposal. In order for CDPF's to be commercially feasible, and customer acceptable, the frequency, cost, inconvenience, and downtime associated with filter cleaning must be minimized.

While there are no apparent barriers to successful filter cleaning and ash removal, the cost and burden issues identified above must be addressed.

D. Exhaust Back Pressure

Another of the issues that must be managed and addressed for the successful commercialization of CDPF's is exhaust back pressure. An increase in exhaust back pressure is inevitable with the use of CDPF's and an increase in exhaust back pressure will, in turn, have a negative impact on vehicle fuel economy. While this is not a technical barrier to implementation, the impacts of increased back pressure will need to be addressed, and minimized. For some high power engines, dual filters may be required in order to avoid excessive back pressure. This will create application packaging and cost issues.

Another issue that must be addressed is the fact that exhaust back pressure will vary as CDPF's go through regeneration and ash cleaning cycles. This could be a problem for filter systems employed on engines using EGR for emission control. EGR flow is dependent on the differential pressure from the exhaust to the air inlet. Back pressure variation may upset the EGR flow calibrations and may have to be compensated for through the development of more sophisticated engine control systems. The need for, and use of, more sophisticated engine control systems will add cost and complexity to the final product and will complicate the development of integrated engine systems.

II. NOx ADSORBERS

The development of NOx adsorbers, and their application to heavy-duty engines and vehicles, is well behind that of CDPF's. Numerous issues must be addressed to assure not only the practical commercialization of NOx adsorber technology, but its fundamental technological feasibility. The availability and use of ULSD is essential to the use of NOx aftertreatment.

A. Temperature Range

Current experimental NOx adsorber technologies have a narrow temperature window in which NOx emissions can be successfully converted. While progress has been made in expanding the NOx conversion temperature window, most of that progress has been shown only in laboratory bench tests under idealized conditions. Those experiments do not represent practical, full scale systems.

In order to meet regulatory requirements, and to be customer acceptable, full scale adsorber systems ultimately must be approximately 95% efficient over the full range of engine and vehicle operating conditions (e.g. cold and hot temperatures, low and high loads, idling and rated speed, varying duty cycles). And, such adsorber systems must be highly efficient throughout all phases of the NOx and SOx regeneration cycles.

Technical breakthrough will be needed to meet these requirements. While there is still time for such technical breakthrough, engine manufacturers (and their customers) do not have until 2007. Rather, if the required breakthroughs have not occurred by mid-2003, manufacturers will not have adequate leadtime to do the necessary vehicle integration, to conduct durability and field testing and to obtain capital, order tooling and approve production parts.

B. Thermal Durability

For NOx adsorber systems to be both technologically feasible and customer acceptable, such systems must be capable of withstanding frequent desulfation cycles and the high temperatures associated with desulfation. The thermo-chemistry of sulfur regeneration requires very high temperatures (up to 650° C) to achieve desulfation in a reasonable time period. However, at such high temperatures, and over the frequent periods of desulfation that NOx adsorbers will be required to withstand, the catalyst washcoat begins to sinter (deactivate). Those problems are exacerbated by the fact that the materials that tend to provide a broader temperature window for NOx adsorber operation (e.g. potassium and sodium) are also the materials that are most difficult to desulfate.

The desulfation event is a key reason for the performance deterioration of NOx adsorbers over time. That is not only a high temperature issue, it also is a frequency issue. For heavy-duty engines (e.g. those used in line haul trucks), NOx adsorbers will need to be capable of surviving the frequency of desulfation that will occur over 435,000 miles – the mandated regulatory useful life period for such engines. In fact, in the current marketplace, customers' expectations and commercial acceptance require that engines typically operate 1,000,000 miles or more without a major overhaul.

Technical breakthrough will be needed to address thermal durability and desulfation issues. If the required breakthroughs have not occurred by mid-2003, manufacturers will not have adequate leadtime.

III. SYSTEM INTEGRATION

Historically, engine manufacturers have reduced emissions in heavy-duty diesel engines through the addition of electronic controls, turbocharging, charge-cooling and refinements to the combustion system and other similar improvements in engine technologies. Those modifications were achieved principally by the engine manufacturer, and did not require significant engine and/or vehicle integration for successful commercialization. The 2007 emission limits require a systems approach whereby improvements to all elements of the system (engine, fuel, aftertreatment, lubricating oil, and vehicle) will require modifications which must be successfully in-place, and integrated, if the technologies required to meet the 2007 emission limits are to be successful.

For the most part, separate and distinct industries are responsible for each of the five elements that make up the systems approach. Obviously, that separateness, need for coordination, and need for sometimes iterative rather than overlapping leadtimes, further complicates the already complex system integration issues that must be overcome. And, it is not just one system that must be integrated. Both PM and NOx aftertreatment systems must be integrated with the vehicle and with each other.

Once base technologies for active CDPF and NOx adsorber systems have been demonstrated (and assuming the availability and use of ULSD and properly formulated lube oils), engine manufacturers, in combination and coordination with aftertreatment suppliers and vehicles OEMs, must develop engine/aftertreatment/vehicle systems which maximize the positive benefits and synergies (and minimize the negative impacts) of at least three emission control subsystems: the engine, PM filter and NOx adsorber. The objective, of course, is to meet certain emission limits. But, that objective must be accomplished while minimizing life cycle costs, weight and space requirements, and fuel economy penalties and while also maximizing, and meeting, durability, reliability and customer satisfaction requirements.

Successful system integration remains a challenge, and not only must be achieved in practice, but must be achieved by perception. If systems are not successfully integrated, or are not perceived to be, customers will delay the purchase of newer technology engines and vehicles. Any such delay results in the inability of manufacturers to begin to recoup their capital investment and the inability to begin to realize the emission reductions that new technologies will provide. If the acceptance of the new technologies by the marketplace is substantially delayed, the loss of emission benefits will be severe and the marketplace disruptions will be extreme.

IV. EMISSION MEASUREMENT

Another critical issue associated with the ability to comply with the 2007 emission standards is the need for improved measurement procedures.

In 1994, EPA and industry cooperated in a round-robin test program to assess the variability in emission measurements using the EPA prescribed Federal Emission Test Procedure (FTP). Eight laboratories, including EPA's NVFEL, participated in the test program. The 2-sigma variability in NOx emission measurement over the FTP was found to be 0.15 g/hp-hr (75% of the 2007 standard) in the participating laboratories. The 2-sigma variability for PM measurement was 0.005 g/hp-hr (50% of the 2007) standard). Those values represent the mean variability within a laboratory, variabilities among all the participating laboratories were substantially larger.

The ability to make precise and reliable emission measurements is fundamental to any emission development program. Without reliable measurements, it is impossible to accurately assess the effect of design iterations or even to determine if progress is being made. Manufacturers efforts to make appropriate choices to optimize engine designs will be hopelessly frustrated. In order to conduct an efficient development program, the 2-sigma emission measurement uncertainty must be less than 10% of the emission standard. This will require a five to seven fold improvement relative to the capabilities observed in the 1994 test program.

EPA is aware of this concern and, with industry encouragement and involvement, and has formed a measurement workgroup to identify and implement improvements to the capability of measurement systems.

The workgroup has identified a number of changes that should improve measurement capability. Although the degree of improvement has not yet been quantified, those changes alone will not be adequate to meet the accuracy requirements. Additional breakthroughs in measurement system accuracy will be required to support emission system development work beginning in 2003.

V. SUMMARY AND CONCLUSION

For all 2007 technologies, the availability and use of <15 ppm ULSD is a condition precedent. As discussed above, good progress in development of CDPF and NOx aftertreatment technologies has been made. Significantly more progress has been made on CDPFs. Conversely, much more work and, in fact, technical breakthroughs are required for NOx adsorbers. In both cases, there are too many uncertainties to conclude that success is assured. There still is development time to address the technical challenges and questions that remain to assure cost-effective, customer acceptable, integrated PM and NOx reducing systems by 2007. But, mid-2003 is a watershed decision point for the transition of technology development into product development. By that date, all fundamental technological issues must be resolved to the point that manufacturers can proceed with confidence from product development to successful product delivery.

By mid-2003, each of the elements that define feasibility (functionality, durability, and cost) must have a demonstrated high probability of success and/or any unresolved issues must have a clear path to resolution. If that is the case, there is a very high probability that the applicable emission standards can be met by 2007. Stated differently, if by mid-2003 there are elements of feasibility for which invention or technical breakthrough is still required, then the ability to meet the applicable standards by 2007 is in jeopardy.

We fully support EPA's commitment to further review progress towards compliance in mid-2003. That review should focus on progress in addressing the CDPF active regeneration and related issues and the NOx adsorber temperature, desulfation and durability and related issues, all of which are discussed above. In addition, EPA should assess the availability of any other PM or NOx technologies that might be cost-effective to meet 2007 emission standards. In recognition of the fact that effective emission system development cannot proceed without a capable emission measurement system, an assessment of the capability of emission measurement systems also should be part of the review.

Finally, EPA should continue to review development progress after 2003 with the focus on assessing cost and commercial acceptability of the new technology systems.

Respectfully submitted,

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